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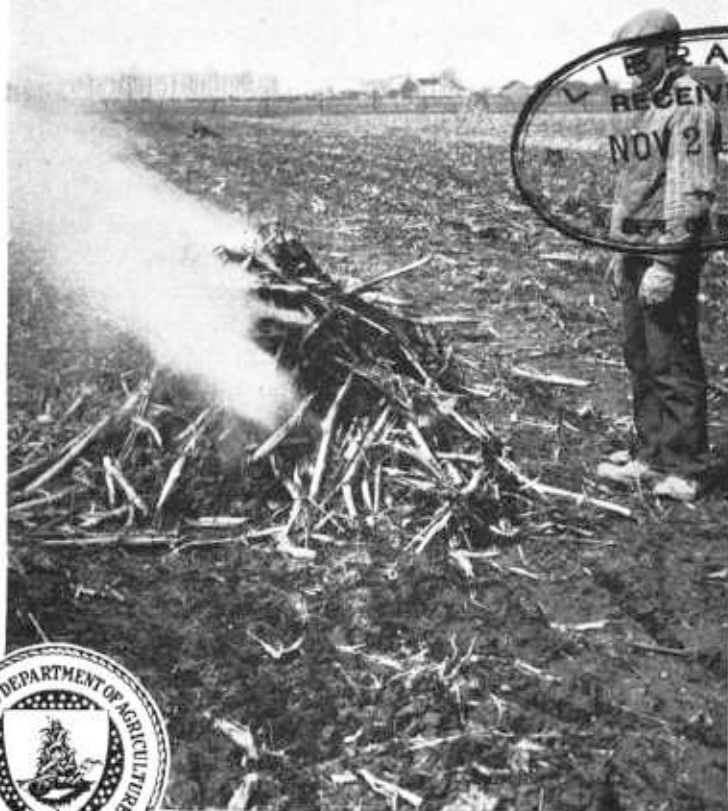
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U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1548

The EUROPEAN CORN BORER

ITS PRESENT STATUS AND
METHODS OF CONTROL



LOSSES IN FIELD AND SWEET CORN due to the European corn borer, in large areas or in severely infested single fields of Canada and the United States, establish this insect as among the most threatening pests of the corn plant that have invaded this country.

After the corn is cut for feed or silage or after the ears are harvested, the borers can be so completely destroyed as to leave few alive to start another year's infestation. The more thoroughly this is done the greater will be the freedom from injury in the succeeding crop.

This bulletin tells about the habits of the corn borer that make it practicable for the farmer to employ protective measures during the winter months and early in the spring. The farm machinery that has been developed to destroy or effectually bury corn borers is also described.

Remember that to accomplish the destruction of the corn borer all remnants of crops that might be infested must be destroyed before moth emergence and that one field left uncleaned or one barnyard with stalks still lying on the ground will furnish an abundance of moths for the entire neighborhood.

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THE EUROPEAN CORN BORER: ITS PRESENT STATUS AND METHODS OF CONTROL

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THE EUROPEAN CORN BORER (*Pyrausta nubilalis* (Hbn.))² is a pest of foreign origin that was first discovered in the United States in the summer 1917. Since that time the best efforts of Federal and State agricultural authorities have been devoted to the task of retarding its spread and of devising methods for its control. Losses due to this insect in field and sweet corn, in large areas or in severely infested single fields of Canada and the United States, show that the borer is among the most threatening pests of the corn plant that have invaded this country.

Investigations have shown conclusively that the eradication of the European corn borer in this country is not possible. It has been found feasible, nevertheless, through improved farm clean-up methods and other cultural practices, to reduce the number of the borers in any given area, and thus provide the most effective available protection from general crop losses by this insect.

¹ The original edition of this bulletin was written by D. J. Caffrey and L. H. Worthley. The revision that was issued in August 1935 was prepared by Mr. Caffrey, who was formerly in charge of European corn borer research in the Division of Cereal and Forage Insect Investigations, and was transferred to the Division of Truck Crop and Garden Insect Investigations March 1, 1934. The present revision was prepared by Mr. Baker.

² Order Lepidoptera, family Pyralidae, subfamily Pyraustinae.

HISTORY OF THE CORN BORER AND ITS KNOWN DISTRIBUTION IN NORTH AMERICA

When the European corn borer was first reported and identified from North America in 1917, it was found to be causing severe damage to sweet corn in the vicinity of Boston, Mass., and to be present in a district comprising at least 100 square miles.

Subsequently it was learned that as early as 1917 the borer was also present in the vicinity of St. Thomas, Ontario, Canada, and in the districts centering around Schenectady and Silver Creek, N. Y.

The exact date on which this dangerous pest gained entrance to North America is not definitely known, but circumstantial evidence accumulated since its original discovery indicates strongly that broomcorn, imported from Hungary or Italy during the period from 1909 to 1914, was the probable means of entrance. The quarantine inspection service at ports of entry was not authorized by law until 1913, or subsequent to the probable original entry of the corn borer into this country.

Figure 1 shows the total area known to be infested in the United States by the end of 1940. The variously shaded portions on the map indicate approximately the areas in which different numbers of generations of the borer predominate annually, although it must be understood that these areas vary considerably from year to year. The multiple-generation strain has been found to occur over practically the entire infested area, although its proportion to the single-generation strain in the Lake States, while varying in different localities and probably reaching its maximum in the southern infested counties of Indiana, is much smaller than in the Eastern States. Wherever the multiple strain is present the number of generations occurring is established by the nature of the environment. A short season in the northern portions of the area is conducive to a single generation, while the long season occurring on the eastern shore of Virginia allows the development of three generations annually. The insect has been found at several isolated points at some distance from the area of general infestation. These isolated infestations have been subjected to intensive clean-up operations.

The corn borer moths are strong flyers, and it is believed that the extension of the infested areas each year is caused principally by flight. Experiments have shown definitely that corn borer moths are able to fly for a distance of at least 20 miles, and judging from their general habits it is probable that they can and do fly greater distances. Large bodies of water do not check their flight, as the moths have been seen to alight on the surface of the water and again take flight. Experiments have also shown that the moths were able to reach cornfields surrounded by high hills or woodlands. During windy periods flight is usually in the direction of, or with, the wind.

It is also known that the larvae can survive long periods of submersion in fresh or salt water when hidden in cornstalks. This fact, plus the fact that cornstalks are known to have been borne long distances in the currents of rivers, lakes, and the ocean, renders it quite likely that many of the new infestations along the North Atlantic seaboard, in the Great Lakes region, and along the river courses of the

present infested area may have had their origin in water-borne infested cornstalks or other infested plant material.

CORN, THE FAVORITE HOST OF THE CORN BORER IN THIS COUNTRY

Corn is infested and injured (figs. 2 and 3) by the larvae, or borers, of the European corn borer to a greater extent than any other crop

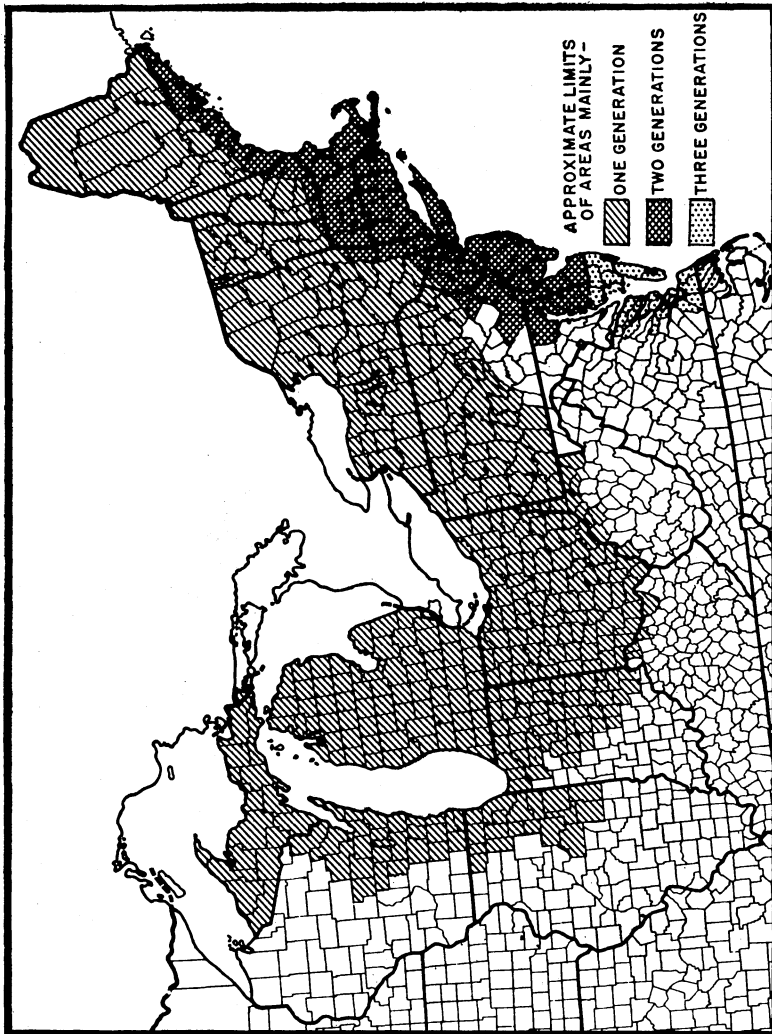


FIGURE 1.—Areas in the United States known to be infested by the European corn borer up to the close of 1940.

attacked by the insect in this country. The borer attacks field corn (both dent and flint), sweet corn, pop corn, and corn planted for fodder or silage. Years of experiments and observation indicate that corn (Indian corn, or maize) is the favorite host of the insect in North America, as it is in Europe.



FIGURE 2.—Corn borer injury to various plants. Top at left: Larvae and pupae in cornstalks; and young tassel attacked by the insect. Male and female moths drawn on same scale as the corn. Top center: A female moth with cluster of eggs on a section of corn leaf, on a considerably larger scale. Top right: Mature tassel showing typical injuries by caterpillar (the broken tassel stem is often the most noticeable evidence of the presence of the insect during the early summer months). Center: External and internal views of injuries inflicted on two ears of sweet corn. Lower half of the figure: Snap heaus, heets, and celery attacked by the borer; cornstalk containing caterpillars; corn stubs cut away to show how the caterpillars hide themselves in the fall, winter, and early spring months; smartweed, which is a favorite food at times; barnyard grass, which in Massachusetts is often heavily infested; and cocklebur plant, a weed that often serves as a breeding place for the pest.

In the Lake States area, comprising western New York and infested States west of New York (fig. 1), corn was practically the only plant that had been injured or infested to any extent on cultivated land by the corn borer up to the end of 1940. A light infestation has been found in some of the more common large-stemmed weeds and grasses growing among the corn or along the margins of badly infested cornfields. Careful examinations under these conditions have revealed the presence of the borer in pigweed (*Amaranthus* spp.), smartweed (*Polygonum* spp.), cocklebur (*Xanthium* spp.), barnyard grass (*Echinochloa crus-galli*), lambsquarters (*Chenopodium* spp.), foxtail (*Chaetochloa* spp.), panic grass (*Panicum* spp.), and similar plants.

The fact should be emphasized that in the Lake States area these corn borer infestations in weeds have been confined to infested cornfields or their margins and are usually caused by the borer seeking shelter in such plants. Several native borers very similar in appearance to the European corn borer (p. 40) are found frequently in vegetables, field crops, flowers, shrubs, or weeds, but only rare instances of corn borer infestations in weeds growing at a distance from corn have as yet been observed, although special and extensive examinations have been made to determine this point.

Under conditions of favorable exposure in the Lake States a light infestation has been observed in some of the cultivated crops and flowering plants, including broomcorn, soybean, millet, buckwheat, potato, pepper, sorghum, dahlia, and cosmos. The number and variety of weeds and cultivated crops infested by the corn borer in the Lake States area will probably increase in the future unless a general attempt is made, by carrying out the recommended clean-up measures, to reduce the number of corn borers to a point where such borers as survive will be confined for the most part to corn.



FIGURE 3.—Ear and stalk of dent field corn showing typical injury done by the European corn borer.

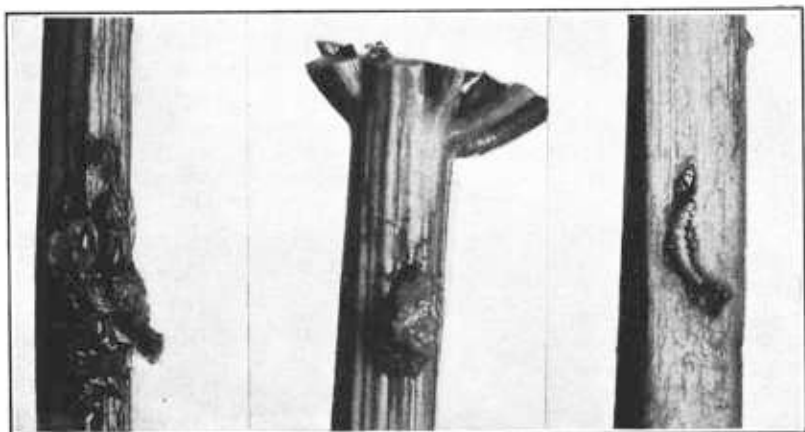


FIGURE 4.—Rhubarb stems infested with the European borer.

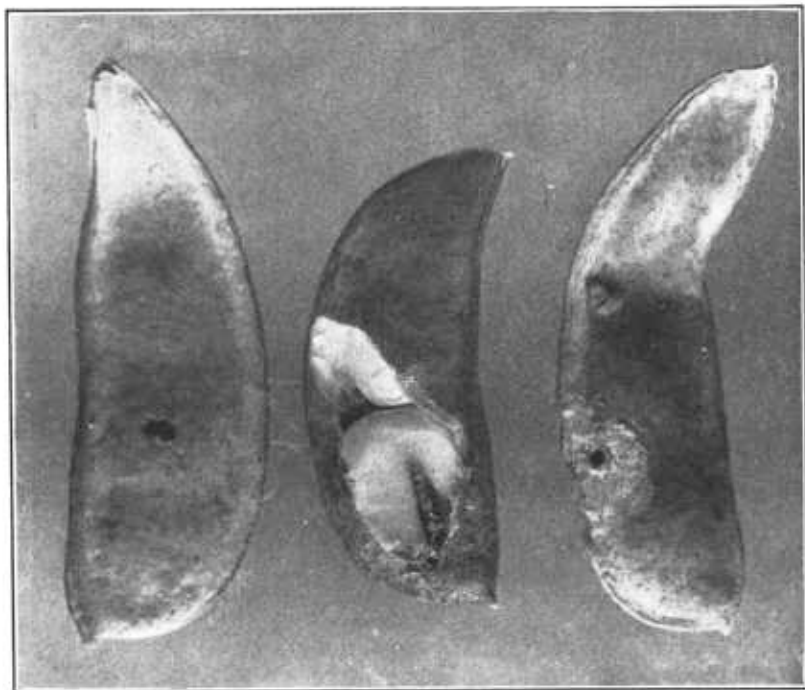


FIGURE 5.—Lima bean pods infested by the European corn borer. One pod cut open to show the borer feeding on the bean within. Borer entrance holes are shown in the other two pods.

In the Eastern States area, comprising eastern New York and the infested States along the Atlantic seaboard (fig. 1), corn is the favorite host of the corn borer, but where two generations predominate in this section the pest commonly lays its eggs upon and attacks many other plants, including vegetables, field crops, flowers, and weeds. Rhubarb (fig. 4), beet, celery, bean (especially lima, fig. 5), pepper, oat, millet, dahlia, aster, gladiolus (fig. 6), chrysanthemum (fig. 7), zinnia, cosmos, hollyhock, and many different kinds or species of large-stemmed weeds and grasses are often injured severely by the corn borer in this section. In fact, over 200 kinds or species of plants in this area have been found to be infested. Many of these plants serve as shelter for the borers, rather than as food, and are infested sometimes by the borers which "overflow" from corn and other favorite host plants growing nearby.

The reason why so many different kinds of plants are more commonly severely infested by the borer where two generations occur in the Eastern States area than in the Lake States is not definitely known. However, where two generations occur the moths developing from the overwintering borers begin laying eggs much earlier in the season than where one generation occurs, and the next brood of moths lays eggs later than do the moths of the single generation. Hence the single-brood moths find corn in abun-

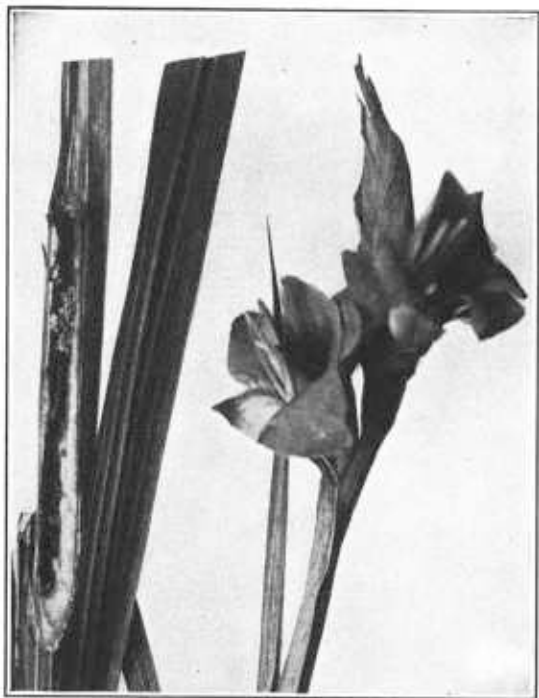


FIGURE 6.—Gladiolus stems showing infestation by the European corn borer.

dance and in an attractive condition, and lay their eggs on it rather than on plants that are less desirable as food for their larvae. Both broods of the multiple-generation moths find many kinds of plants attractive, while there is often a relatively small acreage of corn in a condition attractive to them for egg laying. In those sections where more than two generations occur, similar considerations of host-plant and borer development probably determine the number of different kinds of plants infested. The first generation on the Eastern Shore of Virginia, for instance, is found almost exclusively in potatoes, since there is a scarcity of corn in an attractive condition for oviposition

during the egg-laying period of the moths that develop from the overwintering borers.

CHARACTER OF INJURY TO CORN CAUSED BY THE CORN BORER

The European corn borer is essentially a boring insect and causes its greatest injury by the tunneling and feeding of the larvae within the stalk (fig. 8), ears (fig. 9), tassel, midrib of the leaf, brace roots, stubble, and in fact in practically all parts of the corn plant except

the fibrous roots. In addition the larvae feed to a slight extent upon the surface of the plant, particularly upon the leaf blades (fig. 10), tassel buds, husks and silks of the ear, and leaf sheaths.

The character of the injury inflicted depends on the stage of development of the corn plant when attacked and on weather conditions. Soon after hatching, the borers begin migrating to various parts of the same plant or to other plants in the vicinity. The developing whorl, when available, is a favorite feeding location for newly hatched larvae. If the attacked plant is just developing a tassel, some of the small borers enter the tassel buds and feed within, while others feed on the surface of the tassel buds and protect themselves with a slight silken web. Later they tunnel within the



FIGURE 7.—Injury to stem and flower of greenhouse chrysanthemum done by the European corn borer. Stem cut open to show borer within and type of injury to stem and flower head.

tassel stem and its branches, often causing it to break over. These broken tassels (fig. 11), with bunches of sawdustlike borings at the breaks, are the most conspicuous signs of corn borer infestation in fields of growing corn, although many of the infested corn plants may not show this particular injury. The borers may continue tunneling downward into the main stalk, or they may leave the upper part of the plant and enter it or neighboring plants at points lower down. Some of the newly hatched borers, instead of feeding upon or within the

tassel buds and tassel stalks, enter the stalk directly at some lower point.

The borers usually enter between the leaf sheath and stalk or between the stalk and the base of the partly developed ear (fig. 2),



FIGURE 8.—Hill of sweet corn ruined by the European corn borer. Stalks sectioned to show extensive damage within. There were, on an average, 37 borers per plant in this field.

in case the plant has advanced to that stage of development. As they gradually increase in size their tunnels are made larger, and the borers work upward or downward, according to their individual

preferences, although the majority work upward. Small holes in the plant (fig. 2) with bunches of sawdustlike borings at or below the holes indicate the section in which the borer is at work.

The tunneling of one or two borers in a stalk does not always cause appreciable damage; but when several or many are present within the same stalk, as frequently occurs, it becomes reduced to

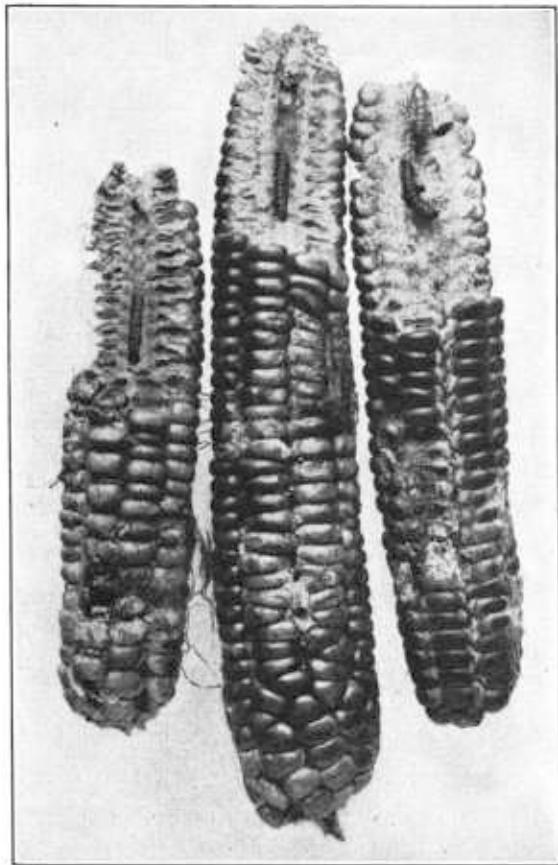


FIGURE 9.—European corn borer injury to grain and cob of flint field corn. Cobs cut open to show borers within. Every stalk and ear in the field from which these ears were harvested was infested.

a mere shell and is filled with fragments of the frass or castings of the borers. Such injury may cut off much of the supply of nutriment from the ear and greatly weaken the stalk, which eventually breaks over. It has been found that corn plants suffering from severe corn borer injury ripen much earlier than uninjured or slightly injured plants.

At any stage of their development the borers may enter the ear directly at its tip, base, or side; or they may enter it indirectly through the short stem, or shank, by which the ear is attached to the stalk, in which case this stem is frequently so weakened by the injury that it breaks over before the ear has completed its development. Ordinarily the ear is entered at its tip by small borers which feed first upon

the silks or the tender portion of the husk, and then work their way down into the cob and grain (fig. 12).

The injury to stalks and ears done by the corn borer may be still further increased by decay, which often follows the work of the borers.

CHARACTER OF INJURY TO PLANTS OTHER THAN CORN

The injury to plants other than corn is of the same general character (fig. 2) as that to corn, except that in some instances only par-

ticular parts of the plants appear to be preferred for food or shelter.

The stems or stalks of celery, rhubarb (fig. 4), potato, hop, oat, barley, buckwheat, hemp, cotton, dahlia, chrysanthemum (fig. 7), gladiolus (fig. 6), aster, zinnia, cosmos, geranium, and other plants are entered and tunneled by the borers, and the borers are sometimes found in the fruits or flowers of certain plants, notably tomato, pepper, cotton, hemp, dahlia, chrysanthemum, and gladiolus.

The stems and leaves of beet (fig. 2), Swiss chard, and other plants are preferred by the borers when attacking these plants. The roots of beet are entered occasionally.

In beans the borers are usually found in the stalks, pods (fig. 5), or green beans.

Not only do the borers cause actual loss by their injury to these crops, but there is also the likelihood that such products, when distributed through commerce, may serve as carriers of the pest to new localities.

The presence of the European corn borer in weeds and wild grasses (fig. 2) is not of itself commercially important, but it affords abundant opportunity for the multiplication and spread of the pest throughout districts where corn is not grown.

DESCRIPTION AND SEASONAL HISTORY OF THE CORN BORER

The single-generation strain of the European corn borer passes the winter as a fully grown borer, or "worm," inside its tunnel in the stalk, stubble, or ear of corn, or in some weed or other plant material growing close to corn.

The presence of the borers may be indicated by small holes on the surface of the infested plants. These holes are usually plugged with the castings of the borers. When these stalks, stubs, etc., are split open, the borers (fig. 2) usually are found within. At this time the borer is nearly an inch long and one-eighth inch thick (fig. 13). The head is dark brown or black. The upper surface of the body ranges in color from light brown to dark brown or to pink. Each division of the body bears a row of small dark-brown spots, while several narrow dark-brown or pink lines extend lengthwise of the body. The underside of the body is flesh-colored and is without markings.

As soon as warm weather begins, in April or May, the borers may leave the shelters occupied during the winter and bore into more suitable places to pass the resting stage.

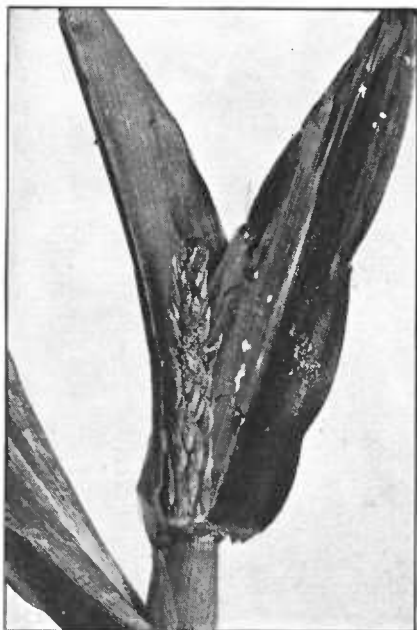


FIGURE 10.—Injury done to leaf blades and tassel buds of corn by young corn borers.

Late in May or early in June the borer cuts a small circular opening from its tunnel to the surface of the plant in order to provide an exit for the future moth. It then closes this hole with a thin portion of silk and retreats into its tunnel to a point near the last feeding or shelter place, where it usually spins a thin cocoon. Inside this cocoon the borer changes into the resting stage, or pupa (fig. 14).

The pupa, or resting stage, is shuttle-shaped, ranges in color from light brown to dark brown, and is from one-half to five-eighths of an inch in length. After a period of from about 10 to 14 days the skin of the pupa splits, and the moth, or adult, comes forth and is present in the fields from late in June to early in August, under average weather conditions.



FIGURE 11.—Broken corn tassel showing injury caused by the larvae of the European corn borer.

yellow, and there are frequently small pale-yellow areas on the forewing.

The moths of the European corn borer resemble several other kinds or species of moths so closely that it is difficult if not impossible for the average person to distinguish between them.

Soon after emergence the females begin to lay their eggs. They remain quiet during the day, hiding in patches of weeds and grass or underneath the leaves of other plants. During the evening and sometimes throughout the night, when weather conditions are favorable, they fly from plant to plant, laying their eggs in flat, irregularly shaped masses (fig. 16). The number of eggs laid by each female moth averages about 400, although the number varies greatly, and a maximum of over 1,900 has been observed. The moths live from 10 to 24 days.

There are usually from 15 to 20 eggs in the average egg mass. As many as 162 eggs have been found in a single mass, although eggs

The female moth (fig. 15, at left) has a robust body and measures about an inch from tip to tip of the wings. The general color is variable and includes all shades from pale yellow to light brown. The outer third of both the forewing and the hindwing is usually crossed by two narrow zigzag lines darker than the rest of the wing. The male moth (fig. 15, at right) has a longer, more slender body, is slightly smaller in wing expanse, and is usually much darker than the female. The general color ranges from pale to dark brown, sometimes with a blue tinge. The outer third of the wing is usually crossed by two narrow zigzag streaks of pale

deposited singly may be observed. These egg masses are laid principally upon the under side of the corn leaves, although they are some-

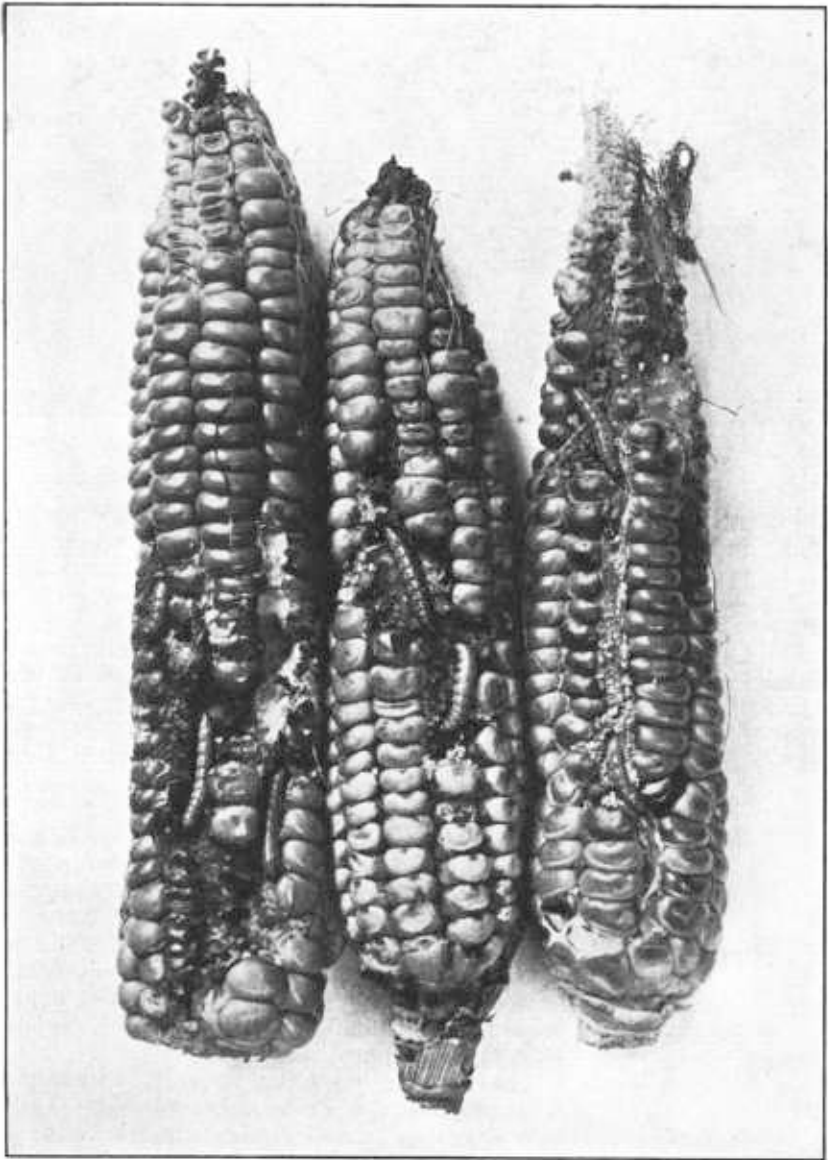


FIGURE 12.—Typical injury done by the European corn borer to the grain and cob of sweet and flint corn. The borers are shown feeding in natural position. The inside of the cobs was also badly tunneled by the borers.

times laid on the upper side of the leaf, on the stalk, or on the husk of the ear. Each egg is about half the size of an ordinary pinhead, and in the clusters the eggs overlap like fish scales. By closely ex-

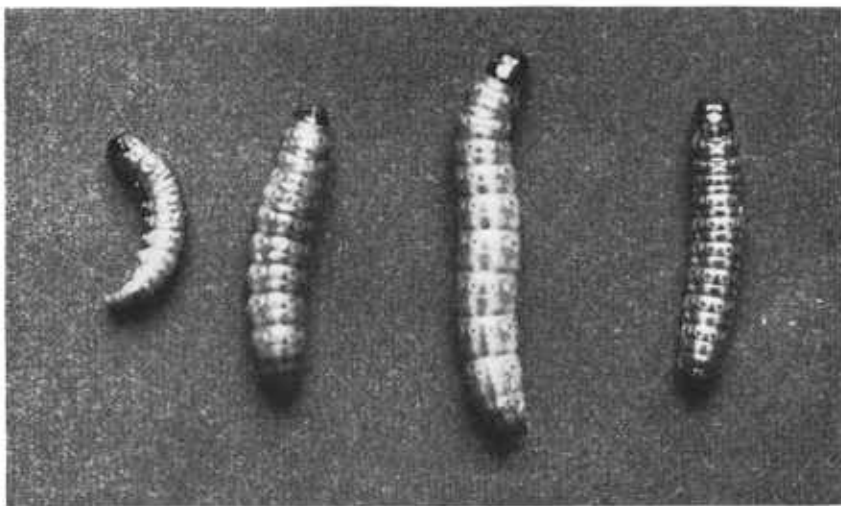


FIGURE 13.—Full-grown larvae of the European corn borer. It is at this stage that the borer passes the winter. Twice natural size.

amining the under surface of corn leaves it should be possible for any person to find these egg masses where the moths are numerous.

The egg is nearly flat and is white when first laid but later changes to pale yellow, becoming darker just before the young borer comes out.

The eggs hatch in from 4 to 9 days, depending on weather conditions. The newly hatched borer is about one-sixteenth of an inch long and has a black head and a pale-yellow body that bears several rows of small black or brown spots. During its growth the borer changes its skin, or molts, five or six times, gradually increasing in size with each change until at last it reaches the stage in which it passes the winter.

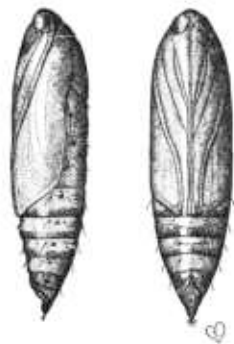


FIGURE 14.—The resting stage, or pupa, of the European corn borer. About twice natural size.

In the Lake States most of the borers become nearly full-grown by the middle or latter part of August if weather conditions are normal. The borers continue to feed, or bore, however, at intervals until cold weather stops their activities in October or November. They remain in a dormant condition throughout the winter within their tunnels in the cornstalks, stubble, cobs, or other plant remnants.

The multiple-generation strain, which predominates in the Eastern States (fig. 1), develops one or more generations per year in accordance with the general type of environment and the seasonal conditions experienced from year to year within the different environments. In the more northern portions of the Eastern States, including parts of New England, when weather conditions are unfavorable for the

borer only a partial second generation develops. Favorable weather conditions produce practically a complete second generation. In the

more southern areas additional numbers of generations develop. Two generations and sometimes a partial third occur in New Jersey, while on the Eastern Shore of Virginia the corn borer has three generations annually. In the New England area, in general, the overwintering borers are entering the pupal stage during May and early in June. The adult moths emerge during June and early in July and lay their eggs during that period. The borers hatching from these eggs are considered to be the first-generation borers.

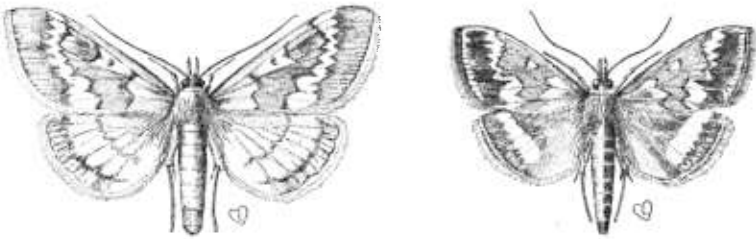


FIGURE 15.—Moth or adult stage of the European corn borer. At left, female moth; at right, male moth. Not quite twice natural size.

Part of these borers (the percentage depending on weather conditions) become fully grown during the period extending from late in July to late in August and enter the pupal stage. The moths emerge from these pupae during August and early in September and lay their eggs throughout these months. The borers hatching from these eggs constitute the second or overwintering generation which develops in the same manner as that described for the first-generation borers. They become fully grown before the appearance of cold weather. These second-generation borers, together with such of the first-generation borers as did not transform, pass the winter in a dormant condition within the stalks, stubble, and cobs of corn and in the stems of a great variety of vegetables, flowers, weeds, and large-stemmed grasses.

The discussion in the preceding paragraph applies particularly to the seasonal development of the corn borer in the district immediately west and north of Boston, Mass. In the more southern infested areas the development starts progressively earlier, the moths emerging from the overwintering resting stage in New Jersey from the middle to the latter part of May and in Virginia during the latter part of April. The average oviposition periods for the three generations on the eastern shore of Virginia start early in May, late in June, and the second week in August, respectively.

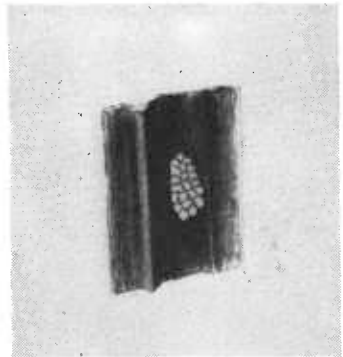


FIGURE 16.—Egg mass of the European corn borer. Slightly enlarged.

CROP LOSS CAUSED BY THE BORER IN THE LAKE STATES AREA

In the area of the Lake States serious injury to corn occurred first in 1926, in western New York, northeastern Ohio, and southeastern Michigan, with crop losses as high as 25 and even 40 percent in the most severely infested fields. In these districts and in Pennsylvania nearly four times as many borers were present as at the same time in 1925. In the Lake States area as a whole there was a yearly increase in the intensity of infestation from 1926 to 1939, with the exception of 1930, 1933, and 1934, when weather conditions were not favorable for the insect. In 1931 the sweet corn in some fields along Lake Ontario in New York was discarded because the canning factories declined to accept the crop. Beginning in 1935, populations built up rapidly in the early-market sweet corn around the western end of Lake Erie and reached an average intensity of more than 17 borers per plant in this type of sweet corn in Lucas County, Ohio, in 1938, with consequent severe crop losses.

IN THE EASTERN STATES AREA

When the corn borer was first reported in the vicinity of Boston, in 1917, it was already causing severe damage to sweet corn. The degree of injury increased up to 1922 as the infested area extended, and not only sweet corn but field corn was badly damaged, approximately 20 percent of the ears, on an average, being infested and some small acreages showing an infestation of from 80 to 100 percent of the ears. Many truck and garden crops, also, were damaged. From



FIGURE 17.—A field of dent corn ruined by the European corn borer. Hightstown, N. J., 1938.

this time on through 1926 the degree of infestation decreased owing to unfavorable weather and the enforcement of State clean-up laws.

From 1927 to 1930 there was a new increase in intensity as well as in the extent of infestation, commercial damage occurring in southern Massachusetts, Rhode Island, Connecticut, and eastern Long Island, and the infestation covering all of eastern and southern New England and large parts of New Jersey. By 1933 the losses in Connecticut to field corn were in places as high as 56 percent, and some fields of sweet corn were plowed under as a total loss.

Heavy concentrations of borer populations in sweet corn in Connecticut have continued, the average population of almost 20 borers per plant in early-market sweet corn in New Haven County in 1939 being the heaviest infestation thus far observed in the United States. Other areas of severe damage to sweet corn occur in the Hudson and Connecticut River Valleys in New York and Massachusetts, respectively. Damage to field corn in central New Jersey in 1938 (fig. 17) was as severe as any previously observed in this type of corn in the United States, and conditions were comparable to those observed in Ontario, Canada, during the very severe outbreak there in 1926. Hundreds of acres sustained a loss of over 50 percent of the crop, and some fields were practically ruined.

IN CANADA

At the close of 1925 the infestation in Ontario, Canada, had become so serious that in counties where the best dent corn in Canada had formerly been grown the corn crop throughout an area of at least 400 square miles was completely ruined. In 1926 in an area of about 1,200 square miles the corn acreage had been reduced to about 10 or 15 percent of that of 1922. Many fields suffered a complete loss of the crop, and losses of 75 percent were common. Less favorable weather for the borer and compulsory clean-up of the fields since 1926 have improved conditions from year to year, although the infestation in Kent and Essex Counties in Ontario in 1937 was the third highest on record.

IN EUROPE AND ASIA

The European corn borer has long been recognized in Europe and Asia as one of the worst pests attacking corn, millet, hops, hemp, and similar crops. Although it seldom causes severe damage in those Old World areas where all infested corn remnants and other crop remnants are customarily destroyed by burning or plowing or are used for feed or fuel, it causes heavy losses in areas where large quantities of corn remnants are customarily left on the farms from year to year, as is now commonly done in the American Corn Belt.

NATURAL ENEMIES OF THE CORN BORER

NATIVE INSECT PARASITES

Although quite a variety of native natural enemies of the European corn borer have been recorded from this country, they do not usually attack the pest in any important numbers and, from present indications, cannot be relied on to hold the borer in check.

Extensive studies of the native insect parasites of the corn borer in the Lake States area have shown that only a fraction of 1 percent of the borers were being destroyed by them. In a similar manner it has been found that less than 1 percent of the borers, on an average, were killed by native parasites in the Eastern States area of infestation, although 24 different kinds of parasites were attacking the corn borer in that area.

INTRODUCED INSECT PARASITES

Since the native insect enemies of the corn borer have been of little consequence, it seemed important to investigate the foreign parasites that were preying upon the corn borer in its native homes, particularly in France, Italy, Belgium, and Hungary, and in various

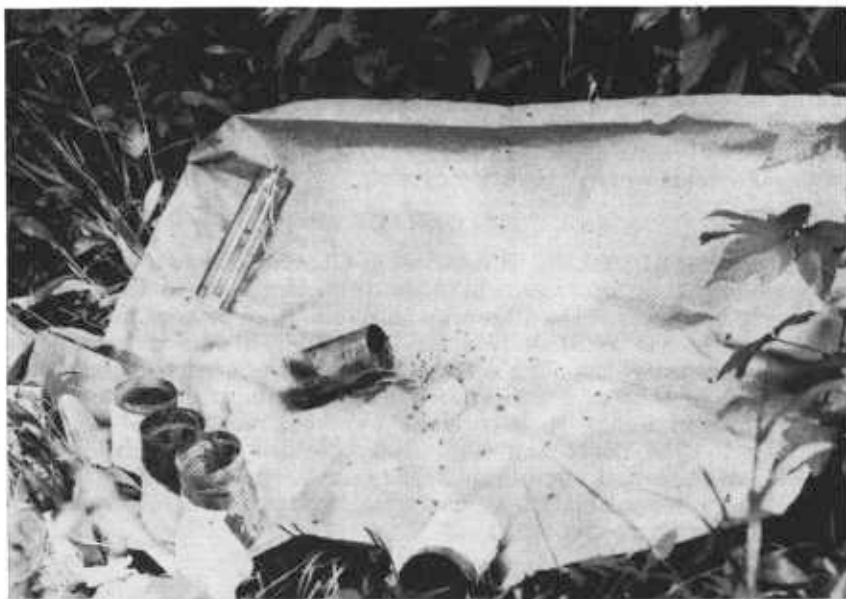


FIGURE 18.—Liberating foreign parasites of the European corn borer.

countries of the Orient. As a first step, however, it was necessary to make careful studies of such parasites in the countries mentioned. These studies revealed several kinds of parasites that were helping to check the ravages of the pest. After it had been determined that none of them could by any possibility become harmful to plants, they were sent to the United States and liberated (fig. 18) close to cornfields, or infested plants, where the corn borer was most numerous. Special precautions were taken, of course, to prevent the introduction with them of natural enemies of the parasites (known as hyperparasites).

The importation of parasites from Europe and from the Orient was supplemented by extensive breeding work under laboratory conditions in this country, as a result of which these imported parasites were greatly increased in numbers before being liberated in infested fields.

From foreign importations a total of over 2 million adult parasites have been available for release in the infested area of the United States. These have been supplemented with over 3 million adults secured through laboratory breeding programs and domestic field collections in eastern Massachusetts, where at least three species of imported parasites have become established and have been so numerous that they could be obtained more effectively from this source than from either importation or laboratory breeding.

Twenty-one different kinds of parasites have been released over the infested area, and four of them have responded very well to conditions prevailing in different localities in which they have been under observation. In the Lake States the only promising species is a tachnid fly, *Lydella stabulans* var. *griseescens* R. D., which restricts its activities to sections bordering marsh areas of Lake Erie. Although it is abundant only in a narrow band in these sections, fields in which over half of the borers have been killed by this fly were commonly observed, and numerous fields have had over three-fourths of their infesting corn borers destroyed by this parasite. Two other imported parasites, *Eulophus viridulus* Thoms. and *Chelonus annulipes* Wesm., are established in the Lake States, but they occur in such small numbers and restricted distribution that their contribution to control at present is negligible.

In the Eastern States all four of the promising species (*Lydella stabulans* var. *griseescens*, *Inareolata punctoria* (Roman), *Macrocentrus gifuensis* Ashm., and *Chelonus annulipes*) are well established in one or more of the liberation sections, and parasite populations are continually increasing, particularly around Hartford, Conn., and in the section extending south of Boston, Mass., to Providence, R. I. In those sections where the parasites are most abundant, over one-third of the overwintering and summer generations of the borer are being destroyed by these parasites, and fields in which over half of the borers had been destroyed by parasites have been frequently observed.

The Parasites Cannot Harm Plants

It should be understood that none of these parasites can, through any chance, become harmful to plant growth, as they are parasitic exclusively on insects and never depend on plants for food.

The Parasites Cannot Be Depended on to Control the Borer

Although strenuous efforts have been made to import and establish parasites in the North American areas infested by the corn borer, it is by no means certain that they will prove to be effective aids in control. Even with the best of success, several years may elapse before any important effect can be expected. In the meantime every effort should be made to control the corn borer by the methods discussed in this bulletin.

BIRDS AND OTHER ENEMIES OF THE BORER

With the exception of feeding by woodpeckers in some localities, birds are not known to have an important influence in reducing the numbers of the corn borer in the infested areas of the United States. In some of the large cornfields in the Lake States and in many of the small garden patches in the Eastern States the downy wood-

pecker (*Dryobates pubescens* (L.)) has been known to remove and destroy from 17 to 95 percent of the borers in the cornstalks and other host or shelter plants. In the winter of 1932-33 woodpeckers destroyed 30 percent, on an average, of the borers in 20 cornfields examined in Ohio and Indiana.

Robins, grackles, blackbirds, starlings, crows, and Mongolian pheasants also are known to feed on the corn borer. Careful observations in connection with plowing experiments in Ohio, in cooperation with State authorities, showed that robins and other birds were devouring at least 15 percent of the borers that had crawled back to the soil surface after infested cornstalks had been plowed under. The Canadian authorities report that crows removed and devoured about 25 percent of the corn borers from broken-over cornstalks in certain badly infested fields of Essex and Kent Counties, Ontario, during the winter and spring of 1926-27.

Various insect predators, spiders, mites, rodents, and skunks have been observed preying on the corn borer in restricted instances or localities, but to date none of these natural enemies, individually or collectively, have markedly affected the abundance of the corn borer.

DISEASE

The corn borer is comparatively free from attack by disease. However, in 1931 investigations were started with a fungus, *Beauveria bassiana* (Bals.) Vuill., which was known to attack the borer in the Orient. Experiments to date have shown that the corn borer is very susceptible to this disease. Spores of the disease were dispersed in test spots throughout the corn borer-infested districts. Although a few borers killed by the disease have been found, there are no present indications that this fungus will become an aid to the natural control of the pest.

METHODS OF CONTROLLING THE CORN BORER

Experience in fighting the European corn borer has shown that the pest may be controlled most effectively by utilizing or destroying all parts of infested plants each year before the insects develop from the borer stage into the moth, or adult, stage. Under practical farm conditions this means that all infested plants must be disposed of principally through any one of the following methods or by a combination of such methods: (1) Feeding to livestock direct, or as silage, or as finely cut or finely shredded feed; (2) plowing under deeply and cleanly; and (3) burning completely.

In presenting the following information on methods of controlling the corn borer, attention is again directed to the point that the habits of the insect in the Lake States area differ in some important respects from its habits in the Eastern States area. In the Lake States area corn is practically the only plant directly attacked by the corn borer, and therefore the main control effort should be directed against corn, whereas in the Eastern States area the corn borer attacks, in addition to corn, such a great variety of vegetables, field crops, flowers, and large-stemmed weeds and grasses that the remnants of these additional plants must be included in farm disposal or clean-up operations. Particularly important, in the Eastern States area, are the large areas of weeds growing in waste or unoccupied lands (fig.

19). Such areas must be cleaned up by burning while the plants are dry or by the use of weed killers while the plants are in a green, succulent condition. In the Lake States area the corn borer mainly develops only a single brood each year, whereas in the Eastern States area there are two or more broods of the borer per year, and the insect begins its activities earlier in the season and continues them later than in the Lake States.

Experience with the corn borer has shown the desirability, whenever agricultural conditions permit, of disposing of infested corn-stalks and other infested plant residues in the fall, especially in fields, gardens, or weed areas which cannot be plowed or otherwise handled effectively in the spring. This applies particularly to fields



FIGURE 19.—Mixed weed growth, mostly barnyard grass and pigweed, in the two-generation area of the European corn borer, on land formerly cultivated. This tract averaged 84 corn borers per square yard.

in which the rotation calls for seeding small grains in the spring and in which the character of the soil is such that it cannot be successfully prepared for small grains or other crops by spring plowing.

Since the corn borer develops into the flying and egg-laying stage late in the spring or early in the summer, it is plain that, in order to prevent the multiplication of the pest, all infested corn plants and corn remnants should be disposed of before that time. For safety such disposal should be made before the first of May of each year in areas north of New Jersey and by the first of April in New Jersey and farther south.

Although many of the foregoing recommendations require a radical departure from present farm practice, such changes are necessary under conditions of serious infestation if the pest is to be controlled.

Control of the corn borer is dependent on a community-wide effort because the moths can fly from field to field and thus spread an infestation long distances. The moths emerging from a single uncleaned or poorly cleaned, infested field can reinfest many other fields that have been properly cleaned up.

In summarizing the general control methods it should be emphasized that the particular method adopted is optional so long as the infested plants and the crop remnants are disposed of by being fed to livestock, or by being plowed clean, or by being burned clean, or by any other method that kills the borers contained in the remnants.

Each field presents a separate problem, and clean-up methods will naturally vary according to the type of farming practice used.



FIGURE 20.—Corn binder with low-cutting attachment at work in a field infested by the corn borer. Such low cutting, if cleanly performed, results in practically 100 percent of the borers being removed from the field in the fodder or being placed in the shock, where they will be destroyed in the spring clean-up. (Illustration from Bureau of Agricultural Chemistry and Engineering.)

FEEDING INFESTED PLANTS TO LIVESTOCK

The feeding of infested plants to livestock is one of the most effective methods of fighting the corn borer and is also a very desirable farm practice. The food value of the fodder is not noticeably injured by the corn borer except in cases of severe infestation. Infested corn plants may be fed as silage, or direct from the field, or in the form of finely shredded or finely cut fodder. When properly carried out, any of these methods of disposal results in the destruction of nearly all the borers contained in the plants.

To obtain the best results with the silo, under corn borer conditions, the infested plants should be cut as close to the ground and as early in the season as possible. Any borers that escape the silage cutter are destroyed in the silo.



FIGURE 21.—Stubs showing corn borers concentrating near the ground level. One stub is cut open to show the borers within; the other shows the entrance holes made by the borers. This picture illustrates the necessity for cutting cornstalks close to the ground.

Infested cornstalks must be cut into pieces not longer than half an inch in order that practically all the borers may be killed. This precaution is particularly important in instances where the silage is not placed directly in the silo or is not fed soon after it is cut.

The use of special, low-cutting attachments for corn binders (fig. 20), which are obtainable from some of the larger implement manufacturers, is strongly recommended. Experiments have shown that when cornstalks are cut about the middle of September at least 3 percent of the borers are left in stubble 3 inches high, and at least 7 percent are left in 6-inch stubble. In general, the number of borers living in the stalk (fig. 21) below any given height triples between the middle of September and the first week of November, as the borers move down through the stalk toward winter quarters.

A home-made sled harvester has been developed, in cooperation with the Bureau of Agricultural Chemistry and Engineering, which effectively cuts at the ground level the stalks intended for silage or fodder. This implement is particularly adaptable to acreages too large for hand cutting and too small to warrant the purchase of a corn binder with low-cutting attachment.

It is plain that where cutting is the accepted farm practice the corn should be cut as low and as early as possible. Such low cutting also helps in doing a clean job of plowing later on and facilitates any other clean-up methods used.

In actual practice the use of short-handled, heavy hoes has been found effective and practicable in many instances where the corn is to be cut by hand. By this method the corn can be cut at, or very near, the surface of the ground. The use of hoes for cutting corn has come into increasing favor with farmers, particularly in the smaller fields, where remarkably good jobs have been performed with this tool.

Feeding Direct From the Field

When infested cornstalks are fed direct (fig. 22) without previous cutting or shredding, the uneaten parts should be collected and destroyed, preferably by burning, unless they are trampled completely by livestock and thoroughly mixed with the manure of the feed lot.

It is dangerous to allow large quantities of cornstalks to accumulate in barnyards and feed lots (fig. 23) unless they are treated, before moth emergence each year, in the way described in the preceding paragraph. Examinations of cornstalks gathered from barnyards and from the surface of manure piles on typical farms have shown as many as 256 borers per 1,000 linear feet of stalk. It is apparent that such stalks may constitute an important source of corn borer infestation in the following season. No living borers were found in thoroughly trampled cornstalks or in finely cut or finely shredded corn fodder that had been used for feed or bedding.

Effect of Embedding or Trampling Infested Cornstalks in Manure

Experiments and observations on infested farms have shown in general that many corn borers survive in cornstalks placed in the ordinary farm manure pile and migrate in large numbers from the piles to seek shelter in surrounding objects. It is therefore strongly recommended that farmers avoid placing infested material in manure



FIGURE 22.—A common source of infestation by the European corn borer: Remains of whole cornstalks fed direct to livestock in pasture and feed lot. These remnants should be raked into piles or windrows and burned.



FIGURE 23.—A barnyard feed lot that was not sufficiently trampled by livestock. Approximately 15,000 exposed stalks containing nearly 39,000 corn borers. All dry parts of such stalks should be collected and burned, unless completely trampled by animals and thoroughly mixed with the manure.

piles, that all manure from piles containing infested material be cleanly plowed under early in the spring before larvae begin to migrate in large numbers, and that all plant remnants be removed from barnyards and destroyed or buried.

The number of borers that survive in properly handled feed lots was observed to be so small that any treatment of the stalks in addition to their being trampled by animals is believed to be unnecessary. It is essential, however, that the trampling be thoroughly done and that no dry or unbroken sections of cornstalks be left on the surface of the feed lot. When all plant remnants are thoroughly mixed with manure by trampling, no other treatment need be given. The time of trampling seems unimportant, except that it should be completed before the emergence of the moths. If the stalks in feed lots have been insufficiently trampled and still contain living borers, they should be completely plowed under before moth emergence.

It should be emphasized that under ordinary farm conditions the large uneaten parts of corn fodder should not be put in the manure unless they can be completely trampled in by livestock.

Husker-Shredder Machines Are Very Effective in Killing Borers

Shredding or cutting corn fodder into fine pieces, as is ordinarily done by husking and shredding machines, kills from 95 to 98 percent of the borers and renders the fodder more acceptable to livestock. This result was obtained in tests with several types of husking machines, commonly termed "shredders," equipped with shredder heads or cutter heads, or with combination shredder and cutter heads. The effectiveness of the machines was increased where special care was taken to apply sufficient pressure on the snapping rolls to produce a crushing effect and prevent long pieces of the fodder from being whirled through the head without being finely cut or shredded. Also, the speed recommended by the manufacturer should be maintained, and the machine should be fed evenly. Department of Agriculture Farmers' Bulletin 1662, *Husker-Shredders in Corn-Borer Control*, contains many suggestions and explanatory illustrations regarding the operation of husker-shredders under corn borer conditions.

It has been found that most of the borers that escaped death in the machine perish during the process of storing the shredded material, feeding it to livestock, and using the residue as bedding, which is finally trampled into the manure, in general practice.

This method of disposing of fodder is strongly recommended, and its use in the corn borer territory should be greatly extended.

Inasmuch as many live borers may drop from this machine directly to the ground or pass through with the shelled corn, not only is it necessary to clean up carefully around the machine, but it is very essential that all remaining trash be disposed of properly. Feed the shelled corn and fine trash to chickens or hogs. Burn all the rest of the trash gathered from around the machine after the shredding operation is completed; do not put such trash in the mow.

The Cutting Box Is Effective if Adjusted Properly

The cutting box has proved effective in killing borers contained in cornstalks, if adjusted so as to cut the stalks in pieces not more

than one-half inch long. Ordinary adjustments that cut stalks into pieces from 1 to 4 inches or more in length do not kill many borers and should not be used.

Feed Grinders and Fodder Mills, or Mealers, Are Effective

Machines that grind roughage into a mealy consistency are popular with many feeders who want to feed roughage in its most edible form and who wish to control the feed content by using a combination of hay, cornstalks, or other roughage, and grain ingredients. These machines are ideal corn borer weapons when the roughage is ground fine enough to destroy the borers. For corn borer control their use is practical and economical. Some farmers who have tractors may be interested in owning one of these mealers cooperatively with their neighbors.

Be sure to clean up properly around the machine after the grinding operation is completed. Unground trash lying around the machine or scattered between the mow and the grinder may contain live borers.

PLOWING DEEP AND CLEAN

Clean plowing under of infested cornstalks, stubble, and other corn remnants is a very effective method of corn borer control. This method is limited to soils that are in a condition to permit clean plowing and the preparation of a satisfactory seedbed before the corn borer moths emerge.

Effective plowing from the standpoint of corn borer control depends on turning under the corn remnants and other trash so completely that none of it remains upon the soil surface. It is essential, also, that the material plowed under should not be dragged to the soil surface by later cultivation before the moths emerge and that the soil surface should be cultivated or pulverized to close all large cracks and crevices.

The plowing under of infested material does not of itself kill the borers. Most of the borers crawl up to the soil surface sooner or later. Where the plowing has been done in a clean manner, however, they cannot find any shelter and soon perish as a result of exposure to the weather, or to natural enemies, which include birds, ants, ground beetles, and various insect parasites and predators. If, on the other hand, the plowing has not been done cleanly, these borers upon reaching the soil surface bore into any fragments of a corn plant (fig. 24) or weed that may be left on the surface, and with this protection they are able to complete their development to the moth stage.

The choice of the plow and attachments, and the previous treatment, if any, of the stalks or stubble can be left to the judgment and experience of the farmer, provided it is kept in mind that the stalks, stubble, and other material must be turned under cleanly and not brought to the soil surface by later cultivation.

The depth of plowing for corn borer control is not important, *provided all infested material is covered completely to such a depth that it will not again be brought to the soil surface by later cultivation or weathering*, to act as a shelter for the borers crawling on the surface. In order to insure proper coverage, however, and to reduce

the possibility of the plowed-under material being again dragged to the surface, plowing to a depth of at least 6 inches should be adopted if soil conditions permit.

The time of plowing is not important as far as the actual destruction of the corn borer is concerned. For instance, if the stalks are plowed under late in the summer, or early in the fall, or in the spring, most of the borers contained in the stalks crawl to the soil surface soon after the plowing. If the stalks are plowed under late in the fall most of the borers remain inactive in the stalks all through the winter and then crawl to the soil surface after the soil warms up the following April or May. In either case it is important that they



FIGURE 24.—European corn borer in a small piece of cornstalk on a plowed field. This fragment (natural size) illustrates the necessity for clean plowing.

find no refuse on the surface in which to hide. Where soil conditions permit fall plowing, the necessity for deep and clean plowing is particularly important as a safeguard against erosion and the frost-heaving of material previously plowed under which sometimes results from shallow plowing under certain soil and weather conditions.

Average Plowing Methods Must Be Improved

To be effective as a means of corn borer control, the plowing methods now commonly used in many localities infested by the borer should be improved. Poor or ordinary plowing allows many pieces of cornstalks, stubble, husks, weeds, leaves, and so forth, to remain on the soil surface, thus providing shelter for many of the borers that crawl to the surface after being plowed under. This allows them to change into moths and multiply. For this reason either poor or

ordinary plowing not only does not control the corn borer but in many respects is worse than no effort whatever, because a poorly plowed field (fig. 25) creates a condition that is difficult and expensive to clean up by other methods.

The skill of the farmer in doing a good job of plowing is as important, within reasonable limits, as the size or the type of plow used. Under favorable soil conditions 14-inch-bottom plows equipped with attachments for covering trash give good results when properly adjusted. Specially designed 16-inch- and 18-inch-bottom plows now on the market are well adapted for clean plowing and give good results even when used in standing cornstalks or high stubble. Field experiments with these plows showed that when they are equipped with a



FIGURE 25.—A poor job of plowing. This type of plowing does not control the European corn borer, as the stalks left on the surface provide shelter for the borers that crawl to the surface after being plowed under.

rolling colter of proper size, a jointer, and a chain, or with the covering wires, as hereinafter described (fig. 26), practically all standing cornstalks and trash can be covered without previous treatment. With such equipment the stalks and trash can be turned to the bottom of the furrow so completely that the land can later be prepared for other crops without dragging the turned-under material to the surface.

An effective plow attachment of three wires to aid in turning under trash is shown in figure 26. A No. 9 galvanized wire gives good results. The wires should be about 12 feet long, attached as shown in the illustration, with the outer ends left loose. In operation the loose ends are caught by the furrow slice as it is turned over. In this manner the wires are held tightly to the top of the furrow slice by the weight of the soil on the buried ends of the wires, and this turns all trash to the bottom of the furrow.



FIGURE 26.—An effective use of three wires to aid in turning under cornstalks and other trash. The wires are about 12 feet long and the ends are left trailing.



FIGURE 27.—Clean plowing with the aid of trash guides. These aids to clean plowing can be easily made and attached to existing plowing equipment. (Photograph by Bureau of Agricultural Chemistry and Engineering.)

The Bureau of Agricultural Chemistry and Engineering has developed a trash guide for attachment to ordinary plows (fig. 27) that in all tests to date, under widely varying field conditions, has given a very thorough and deep coverage to heavy growths of cornstalks, high stubble, and other plant refuse.

If the available equipment is not sufficient for plowing entire cornstalks or high stubble completely under, the stalks or stubble should be cut at the ground level, raked into windrows or piles, and burned as cleanly as possible, or some other effective treatment should be used. Any remaining parts may then be plowed under entirely.

Circular 132 of the United States Department of Agriculture, *Fighting the Corn Borer with Machinery in the Two-Generation Area*, contains many suggestions and explanatory illustrations regarding plows and good methods of plowing, under corn borer conditions.

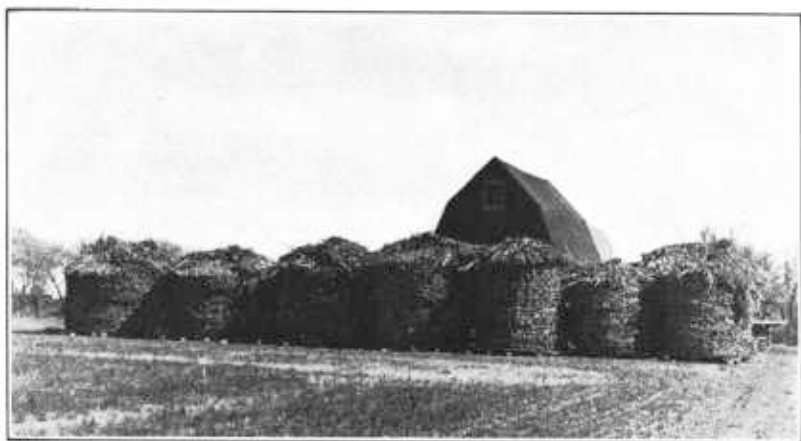


FIGURE 28.—Wire corncribs thatched with infested cornstalks. These stalks are a source of infestation unless disposed of by burning or otherwise before the moths emerge.

BURNING INFESTED PLANTS

Burning is one of the effective methods of disposing of such infested cornstalks or other plant material as cannot be fed to livestock or plowed under cleanly. This method, however, may not be generally considered a good farm practice from the standpoint of returning as much organic matter as possible to the soil. Nevertheless, if control is to be achieved, the burning of cornstalks and other crop residues infested with corn borers seems justified and must be adopted when the material cannot be effectively disposed of in any other manner. The method of burning infested plants may vary in accordance with the prevailing farm practice. In case the corn is cut and shocked the problem is comparatively simple, since any surplus shocks can be burned where they stand or, if necessary, hauled to a suitable location and burned before moth emergence each year. This should include all cornstalks that have been used in building shelters for livestock, for thatching (fig. 28), windbreaks, or similar purposes, as well as surplus stalks stored for feeding purposes, and cornstalks along ditchbanks and field borders.

If the ears are husked from standing stalks the problem of burning the stalks completely becomes more difficult. The main point to keep in mind, however, is that all corn remnants should be fed, plowed under, or burned. If burning is considered the best solution

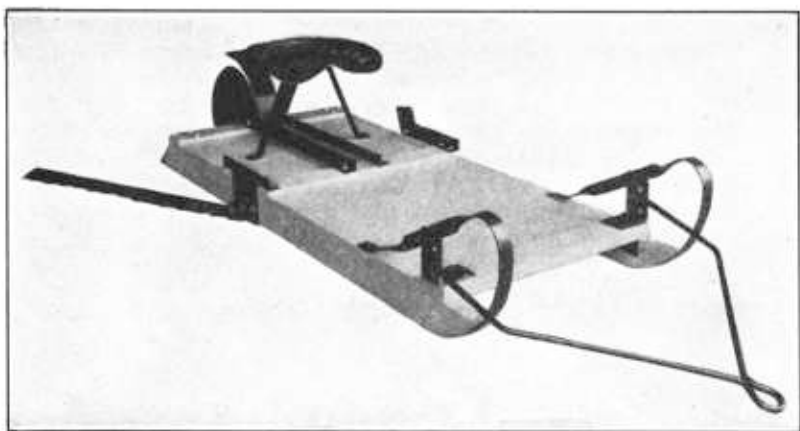


FIGURE 29.—A home-made stalk shaver for cutting off the stalks at the ground surface preparatory to raking and burning.



FIGURE 30.—Cutting four rows of cornstalks with two stalk shavers drawn by three horses.

of the problem, several methods of procedure are possible. The stalks may be cut at or close to the ground level with any of the available types of stalk shavers or with a short-handled heavy hoe in the case of small fields in which such a method is practicable. When dry, the stalks should be raked cleanly into windrows or piles and burned

completely, even though it may be necessary to resort to hand methods in raking stalks into the fires.

Many types of regular farm equipment and special tools have been used to cut off standing cornstalks or other infested plants. One of the most effective devices perfected to date consists of a simple home-made sled-type stalk shaver (figs. 29 and 30). This stalk shaver is ideally adapted for slicing stalks or high stubble off at the ground surface preparatory to raking and burning. Repeated tests of this device under a wide variety of field conditions have given excellent results, and its use for this purpose is recommended. Directions for the construction of this stalk shaver at home for a small outlay of time and funds are given in Miscellaneous Publication 142 of the United States Department of Agriculture, *Construction of Sled-Type Cornstalk Shavers*.



FIGURE 31.—Raking infested cornstalks into windrows with a side-delivery rake, to be burned, is an effective method of corn borer control if the infested stalks are cut at ground level, raked cleanly, and completely burned. This rake is a four-bar outfit with closely spaced teeth and shields. (Photo by Bureau of Agricultural Chemistry and Engineering.)

In the operation of cleanly raking the cut-off cornstalks, high stubble, or other plant material into windrows, the best success to date has been obtained with side-delivery rakes (fig. 31). The most satisfactory side rake yet obtained has four instead of three tooth bars, carrying closely spaced teeth, the speed of the cylinder remaining normal. On fairly smooth ground this rake has performed a satisfactory job of raking, even with heavy cornstalks.

The common steel-toothed sulky dump rake can be used to rake trash into windrows preparatory to burning, provided that the soil surface is smooth, that the trash is fairly dry and clings together without shattering, and that the operator does not attempt to gather too heavy a load before dumping it. The special close-toothed sulky dump rakes now marketed by some manufacturers do better work on smooth ground than rakes with the ordinary spacing of teeth. In raking

cornstalks, however, the sulky dump rake does not often rake cleanly enough to make plowing unnecessary.

Thus far the practice of hilling corn has proved a handicap in raking stalks cleanly. It is evident that the practice of level cultivation must be resorted to more freely if raking stalks is to be effective in corn borer control.

In order to emphasize the importance of disposing of small pieces of trash on the surface of infested cornfields, it should be stated that careful examinations of the surface of typical infested fields have shown that, on an average, 14 percent of the total original borer population were hidden in small pieces of cornstalks (fig. 24), corn husks, leaves, or weed stems left on the ground after it had been improperly cleaned.

Winter Poling Is Not Effective in General Practice

The practice of dragging sidewise a heavy log or railroad iron across the field to break off the stalks at the ground surface usually allows many of the stalks, though broken, to remain firmly attached, and this prevents a clean raking job. Experience has shown that only on rare occasions, when the stalks are frozen and when there is practically no snow on the field, can poling be done so efficiently as to allow clean raking. Therefore winter poling preparatory to burning is not recommended as a corn borer control measure, and some type of stalk shaver should be utilized as a means of detaching the cornstalks from the soil.

DISKING STUBBLE OR ENTIRE STALK FIELDS IS NOT EFFECTIVE

Disking cornstalks or high stubble (fig. 32) in preparation for seeding to small grain or other crops is a very objectionable practice from the standpoint of corn borer control, except when followed by clean



FIGURE 32.—Typical field of high stubble. This practice of high cutting must be stopped in areas infested by the corn borer, unless such stubble is disposed of by clean plowing, or other means, before the moths emerge.

plowing. Disking not only allows a very high percentage of borers to survive, but the shade subsequently furnished by the growing grain affords protection from the weather to the borers contained in the trash left on the soil surface.

Rolling, "cultipacking," disking, or other types of harrowing are all methods of practically no value in corn borer control.

The present practice of direct disking of high stubble or cornstalks infested with the corn borer, as a preparation for small grains or other crops, must be discontinued if the pest is to be held in check and widespread commercial loss prevented. Disking should be preceded by the operations of cutting off the stalks at the ground level and completely disposing of them, together with all trash, by burning or otherwise.

CORN STUBBLE IS AN IMPORTANT SOURCE OF INFESTATION

It is plain that if the corn is to be cut, it should be cut as low and as early as possible and that all high-cut stubble should be disposed of by the recommended control methods.

The advisability of low cutting as a corn borer control measure in instances where the farm practice involves the cutting of corn is further emphasized by the fact that less than 1 percent of the original borer population of the field is present in the underground portion of the corn stubble.

DESTROYING BORERS IN HOME GARDENS

In many localities susceptible plants in many of the home gardens, especially small patches of sweet corn, often contain more borers per plant than do the large commercial fields. In these gardens susceptible vegetables, flowers, field crops, large weeds, and large-stemmed grasses growing in or along the margins of the sweet corn often contain many borers as a result of migration of the borers from corn or from direct egg deposition by the corn borer moths or from both sources.

While these home gardens are usually small, the total acreage is sufficiently large to harbor large numbers of corn borers in many of the villages, suburbs, and cities in the older portion of the infested areas. Therefore, the clean-up of these home gardens becomes an important part of corn borer control operations. The general procedure is similar to that described for large-scale control methods in the preceding pages. In brief, the infested host-plant residues, such as cornstalks or stubble, flower stalks, vegetable stalks, weeds, and grasses, may be fed to any livestock in the vicinity, plowed or spaded under, buried by hand, burned, or completely disposed of by any combination of such methods as is most convenient, preferably late in the fall.

CONTROL MEASURES THAT MAY BE USEFUL UNDER CERTAIN CONDITIONS

INSECTICIDES

While present costs of insecticidal treatments are too high to permit their general use in combating the corn borer, recent investigations have shown hand applications of spray preparations to be

entirely practical and satisfactory for the protection of the more valuable crops, such as early-market and home-garden sweet corn. A mixture consisting of 4 pounds of ground derris (or cube) root containing at least 4 percent of rotenone, 100 gallons of water, and a spreader,³ used as recommended on the package for this quantity of spray, has been found to provide high protection from corn borer infestations in sweet corn. Tank-mixed nicotine tannate and phenothiazine⁴ have also given satisfactory protection from the corn borer, particularly in Connecticut, although their performance has not been so uniform under all conditions as that of the rotenone preparations.

At least four applications of the insecticides chosen should be made. Regardless of the growth stage of the corn, the first application should be made when corn borer egg masses begin to hatch in the field. This establishes the beginning point of the treatment schedule. The first application should be followed by at least three more applications at 5-day intervals. For example, if hatching egg masses were first observed on June 11 and the initial application was made on June 12, then the schedule of succeeding applications would include June 17, 22, and 27. Field experiments have shown that applications at 5-day intervals are necessary because in this period the insecticide residues become diluted, the plants make rapid growth, thus exposing unprotected surfaces, additional egg masses hatch during such an interval, and protection is thus assured areas likely to be reached by migrating larvae. Seasonal variability and seasonal differences between localities so alter the hatching period that the insecticide-application schedule should be arranged with reference to the conditions of the current season. Experience has shown that the most practical date for the first application can be established through the cooperation of local and State agricultural agencies.

The sprays must be applied so as to insure thorough wetting of the whorl, emerging tassel, developing ear, junctures of leaf blades with the stem, and tiller growth. Sprays may be readily directed at these parts of the plants with a length of hose terminating in a light 30-inch extension rod provided at its base with a lever-operated valve for controlling the spray. Compressed-air sprayers of the portable 3-gallon size (fig. 33) or the larger "wheelbarrow" type (fig. 34) have been found useful in applying the sprays.

Dust preparations containing either dual-fixed nicotine or 1 percent of rotenone (ground derris or cube root) in a dust carrier have given satisfactory control in some years and localities. However, the results have not been so consistent as those obtained with the spray preparations, probably because of variable weather conditions, and at present dusts are not recommended as substitutes for the sprays.

TIME OF PLANTING

Where only one generation of the borer occurs annually, field and sweet corn planted late in April or early in May usually sustains

³ Spreaders are soaplike materials sold in powder or liquid form and packaged under various trade names. Ordinary soap powders should not be used because of their tendency to burn the plants. While there may be other good spreaders on the market, those in powder or flake form composed of sodium butylhydroxyphenylbenzene sulfonate, or sodium sulfo soap, and in liquid form composed of sodium oleyl sulfate and synthetic resinous sticker, have been found satisfactory in experimental tests.

⁴ Detailed information concerning these insecticides may be obtained from the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

the worst corn borer infestation in a given locality. In contrast with this, plantings made the last week in May, or later, ordinarily escape severe infestation by the pest. However, tests with field corn



FIGURE 33.—Hand application of insecticides for the control of the European corn borer, by means of a 3-gallon portable sprayer.

have shown that the smaller number of borers that occur on later planted corn cause a much greater loss per borer than do those on earlier planted corn. This greater damage per borer, plus the reduction in yield associated with later plantings, offsets to a great extent any advantage gained from late planting and suggests that

plantings be made as late as possible only within the normal planting period adapted to the locality.

In any evaluation of the economy of late plantings of sweet corn to reduce borer infestations, the market gardener must consider the relatively higher prices prevailing earlier in the season, while the canner is confronted with the necessity of operating expensive factory equipment over a longer period of time to accommodate crops from large acreages. He must balance this factor, including increased inspection costs, against the value of late planting by the grower to decrease borer infestation and the consequent lessening of the danger of contamination in the canned product.



FIGURE 34.—Hand application of insecticides for the control of the European corn borer, by means of a "wheelbarrow" sprayer.

Under conditions where the pest multiplies twice each year, the first-generation borers tend to be concentrated in the corn planted early (late in April and early in May), whereas the borers of the second brood tend to be concentrated in corn planted after the last week in May. Plantings of field corn made the last week of May or later under one-generation conditions are only lightly infested by the borer, while in those areas where two generations occur these later plantings are frequently subjected to severe infestations from the second generation. These conditions indicate that early and late plantings of field corn should be avoided in those areas where two generations occur and corn is exposed to severe infestations. Similar considerations with reference to time of planting under two-brood conditions also apply to sweet corn.

CHOICE OF CORN VARIETIES

None of the types, varieties, or strains of corn thus far tested under large-scale field conditions has shown any indication of real immunity from corn borer attack. It has been shown, however, that some strains of corn possess inherent characteristics which enable them to resist the borers better than other strains or varieties. The number of borers per plant at harvest as compared with the number of corn borer eggs originally on the plants is much smaller in some strains of corn than in others. Some of these resistant field corn strains are being used in the corn-improvement programs of several States, but those sweet corn strains that have been shown to be resistant to the borer are not available for use in the production of commercial hybrids at present.

TRAP CROPS

Attention has been called to the fact that the earliest planted fields of corn, particularly sweet corn, usually suffer the heaviest corn borer infestation in any given area. This naturally suggested the use of a small area of very early planted sweet corn in fields intended for a main crop of field corn of late-planted sweet corn, to attract the corn borer moths and thus act as a trap crop. Such trap crops *must be destroyed or used for fodder early in the season*. Actual attempts to apply the trap-crop method of control under field conditions, however, have failed to show reliable results from year to year. Trap crops cannot be depended on, but in a favorable season they attract many moths that would otherwise lay their eggs on the main crop of corn.

INEFFECTIVE CONTROL MEASURES

TRAP LIGHTS

One of the oldest and most ineffective methods used in attempting to control destructive insect pests was the trap light, the theory being that since some moths can be attracted to the light they may then be destroyed. Although extensive efforts and much money have been expended in attempts of this nature, the use of trap lights as a method of control has seldom been successful in the case of any insect pest. The trap-light method, in combination with various baits, however, was given a very thorough test in the course of the European corn borer investigations. Repeated observations with many types, kinds, and colors of lights showed that the number of corn borer moths attracted to such lights comprised less than 1 percent of the total number of corn borer moths in the vicinity. It is plain, therefore, that this has no value as a method of corn borer control.

ATTRACTIVE BAITS

Under experimental conditions corn borer moths have been caught in traps baited with a 20-percent molasses solution in water, and while such a trap has proved useful for technical purposes, it is not recommended as an effective means of protecting corn or other crops susceptible to infestation by the corn borer.

CATERPILLARS OFTEN MISTAKEN FOR THE EUROPEAN CORN BORER

Several kinds of common native caterpillars, "worms," or borers are often mistaken for the European corn borer and cause needless alarm. Some of these are similar in appearance to the European corn borer, and others, though very different in appearance, cause damage that often resembles the injury caused by the corn borer. Detailed descriptions and illustrations of many of these borers will be found in various Federal and State publications.

It is important that all corn growers outside the known infested area be on the lookout for the European corn borer. Therefore when any worms, caterpillars, or borers suspected of being the European corn borer are found, specimens should be placed in a tight glass vial containing dilute formalin or alcohol and sent to the Bureau of Entomology and Plant Quarantine, Washington, D. C.

THE CORN EARWORM

On account of the similarity of the damage it does to the ears of corn, the corn earworm (*Heliothis armigera* (Hbn.)) (fig. 35) is very often mistaken for the corn borer. This insect is also known as the cotton boll worm, tomato fruitworm, and tobacco budworm.

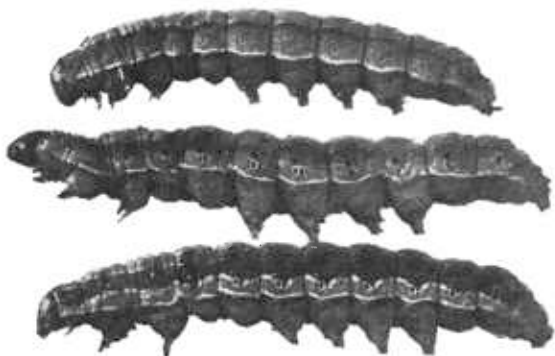


FIGURE 35.—Side view of three larvae of the corn earworm showing the color types: Upper larva, green; middle one, rose colored; lower one, dark brown. Not quite twice natural size.

The corn earworm, however, is not a true boring insect and usually confines its damage to the silks and kernels of the ear, whereas the corn borer not only feeds habitually on the silks and kernels but also bores into the cob. Unlike the corn borer, the corn earworm very rarely bores into the stalks, although if the ears have not devel-

oped on young plants it often feeds on the leaves and in the growing tip, or "bud," of the plant. This injury sometimes results in broken-over tassels that at a distance resemble corn borer damage, but close examination will show that these tassel stems have not been tunneled. This characteristic serves to distinguish such injury from that of the corn borer. Late in the winter and early in the spring corn earworms are never present in the ears of corn or in the stalks, whereas corn borers may commonly be found in ears and stalks of corn at this time in areas in which corn borers are numerous.

The caterpillars of the corn earworm are about $1\frac{1}{2}$ inches long when full-grown and vary greatly in color, ranging from tints of green, pink, rose, yellow, and brown to almost black. They may be beautifully striped, or spotted with brown, black, or yellow along the side and back.

or they may be entirely free from stripes or spots. In appearance they can be readily distinguished from the corn borer by the fact that they are nearly twice the size of the latter. The hairs arising from the black tubercles, or warts, on the back of the earworm are much longer and stouter than those arising from the brown tubercles on the back of the corn borer. The castings of the earworm are coarse, wet, and foul, while those of the corn borer are more finely divided and usually dry. The corn earworm is widely distributed throughout the country.

THE STALK BORER

The stalk borer (*Papaipema nebris* Guen., form *nitela* Guen.) (fig. 36) often occurs in large numbers during the early summer in some sections of the country. They work habitually within the growing tip (heart) and stalk of young corn, and are frequently mistaken for the European corn borer on account of their habit of boring into the cornstalks. They also bore into the stalks, and infrequently into the fruit, of several other cultivated crops and flowers and weeds.

The young caterpillars of the stalk borer are very easy to distinguish from those of the corn borer, as they bear a dark-brown or purple band around the middle of the body, and several conspicuous brown or purple stripes run lengthwise of the body. The corn borer does not possess these conspicuous bands or stripes. As the stalk borer becomes full-grown, however, these bands and stripes disappear, and the color becomes plain creamy white or light purple, and only inconspicuous markings are visible. The full-grown stalk borer is slightly more than an inch long and is much larger throughout than the corn borer. It is never found in cornstalks during the winter.

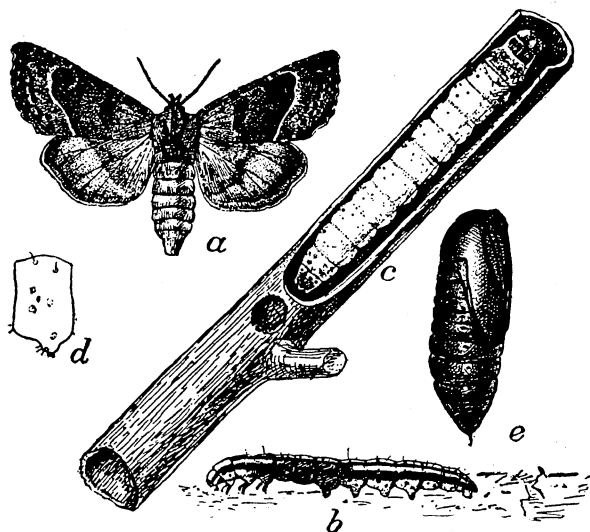


FIGURE 36.—The stalk borer: a, Female moth; b, half-grown larva or borer; c, full-grown larva in injured stalk; d, side view of segment of abdomen of full-grown larva; e, pupa. All somewhat enlarged.

THE SMARTWEED BORER

The smartweed borer (*Pyrausta ninsliei* Heinr.) (fig. 37) is very frequently found in corn during the fall, winter, and spring. The appearance and work of this native borer resemble those of the European corn borer so closely that it is very difficult to distinguish between them. The smartweed borer usually feeds within the stems of smart-

weed (*Polygonum* spp.), but it commonly bores into the stalks of corn and other plants when seeking winter quarters. It is practically harmless to corn.

It is known to be very numerous throughout the eastern part of the country, and many reports of European corn borer occurrence have been due to the presence of the smartweed borer.

The caterpillars of the smartweed borer are about three-fourths of an inch long when full-grown, slightly smaller than the corn borer, and less robust. They are always slate-colored or gray when full-grown, and in the living state they bear a very fine, faint line of darker color running along the middle of the back, whereas in the living corn borer this line is decidedly broader and very conspicuous. Except for these differences and one or two microscopic distinctions discernible only by an entomologist, these two kinds of borers have the same appearance when full-grown. On hatching from the eggs the small

caterpillars of the corn borer have black heads, while those of the smartweed borer have pale amber-colored heads.

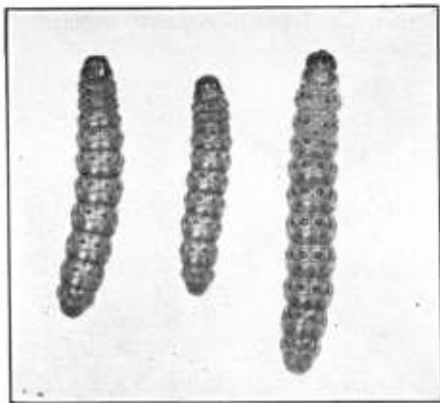


FIGURE 37.—The smartweed borer is very often mistaken for the European corn borer, as they are about the same size. The smartweed borer is found often in corn plants into which it has entered for shelter. Compare with figure 13. Twice natural size.

THE SOUTHERN CORNSTALK BORER

In the Southern States, and especially in the South Atlantic States, the southern cornstalk borer (*Diatraea crambidoides* Grote) is a common enemy of the corn plant, and owing to its habit of tunneling in the stalks of corn it may be easily confused with the European corn borer. The southern cornstalk borer, however, does not bore into the ears of corn, whereas this habit is characteristic of the corn borer. This southern pest habitually overwinters only in the roots of the corn,

whereas the European corn borer not only winters in the stubble but may also be found in the stalks and ears of corn.

The caterpillars of the southern cornstalk borer are of two types—a summer form and a winter form. The summer form, when full-grown, is about 1 inch in length, with a dirty-white body thickly dotted with round or irregular dark spots, each of which bears a short, dark bristle. The head region is brownish yellow. The winter form differs from the summer form in that the caterpillar is more robust and is slightly shorter, while the spots referred to above are of nearly the same color as the body. Along the Gulf coast and on the Mexican border two distinct but very similar and closely related caterpillars may attack corn. These are the sugarcane borer (*Diatraea saccharalis* (F.)) and the southwestern corn borer (*D. grandiosella* Dyar).